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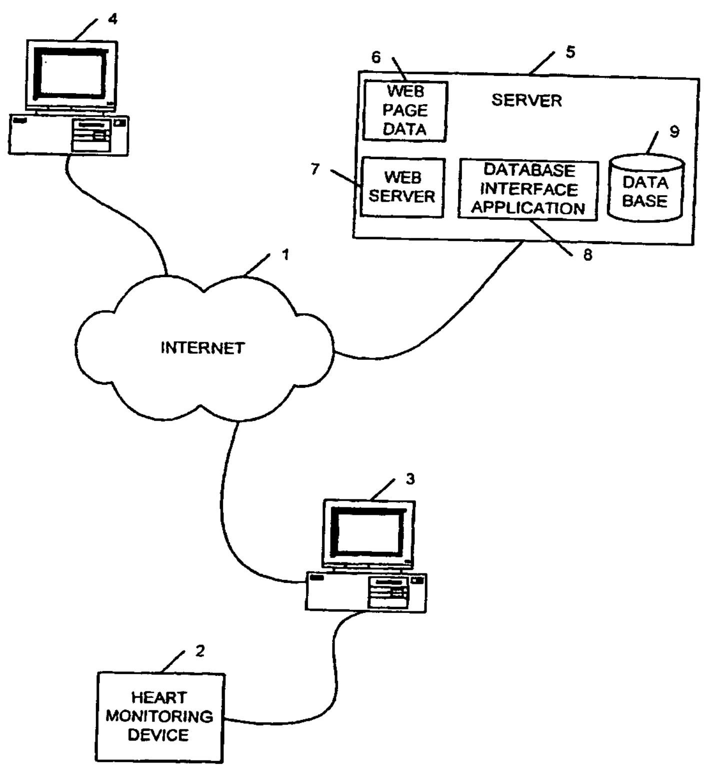
(54) Title: A METHOD AND APPARATUS FOR GENERATING A PHYSICAL EXERCISE PROGRAM FOR A SUBJECT BASED ON CARDIAC STRESS MEASUREMENTS AND A METHOD OF ENABLING A MEDIC TO REMOTELY MONITOR THE CARDIAC HEALTH OF A PATIENT



(57) Abstract: A computerised system and method is described in which a physical exercise program for a subject is generated based on the medical history of the subject and measurements made of the stress experienced by the subject's heart during a previous exercise program. A series of exercise programs can be generated to suite the subject: each program being devised based on the effectiveness of the previous program. Also, a cardiac monitoring method for monitoring a plurality of patients remotely is disclosed in which measurements of cardiac function of a subject are taken, the measurements are processed to generate cardiac data indicative of the condition of the heart of a subject, the cardiac data is transmitted to a database for storage as a record for the subject, the taking of measurements, the processing of the measurements and the transmitting of the cardiac data are repeated for a plurality of subjects to form a plurality of records, one for each subject, and a medic is provided with an interface to access to the records of a number of subjects for which the medic has medical responsibility. The generated exercise program and the heart stress measurements can be used to control an exercise machine during exercise by the subject.

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A METHOD AND APPARATUS FOR GENERATING A PHYSICAL EXERCISE PROGRAM FOR A SUBJECT BASED ON CARDIAC STRESS MEASUREMENTS AND A METHOD OF ENABLING A MEDIC TO REMOTELY MONITOR THE CARDIAC HEALTH OF A PATIENT

The present invention generally relates to a method and apparatus for generating or adapting a physical exercise program for a subject based on cardiac stress measurements. The present invention is particularly suited to cardiac rehabilitation. The present invention also relates to a cardiac monitoring method and system for enabling a medic to monitor the cardiac health of a plurality of patients remotely.

Cardiovascular and circulatory diseases are the largest cause of death in the western world. Patients who have suffered a heart attack, undergone re-vascularisation surgery, or who suffer from congestive heart disease or heart failure are often encouraged to exercise by their doctor. It has been proven that an exercise regime improved mortality rates in the post MI population and improves the quality of life of the patients.

Typical cardiac rehabilitation programmes consist of supervised, class based exercise sessions backed up with walking programmes carried out independently by the patient. Remotely managed programmes tend to include less vigorous exercise prescriptions and suffer from a lower compliance. Some such programmes are monitored through the use of heart rate monitors or telemetry based ECG recorders to allow medical professionals to follow their patient's progress. Such techniques are expensive to operate and time consuming for the medic, as they have to interpret the raw data being transmitted from the patient. It would be desirable and beneficial for a device to monitor and interpret the patient's ECG while they are exercising and for an automatic system to manage the patient's progression with a supervisory role played by the medic.

Heightened awareness of heart disease has also caused many people to reassess their lifestyle. One of the major risk factors for heart disease is a family history. Such

individuals have an incentive to reduce other risk factors by taking part in an exercise programme tailored to their individual cardiac health.

The present invention provides a solution to these problems and provides a computerised system in which a physical exercise program for a subject is generated based on the medical history of the subject and measurements made of the stress experienced by the subject's heart during a previous exercise program. In this way a series of exercise programs can be generated to suit the subject: each program being devised based on the effectiveness of the previous program.

In the present invention the subject can be any animal subject for which an exercise program has a beneficial effect on cardiac function. The invention is however preferably for improving the cardiac function of human subjects by the provision of an exercise program suited to the cardiac capability of the subject.

The present invention can be implemented on a single computer receiving cardiac data indicative of cardiac stress during exercise, or over a network of computers e.g. over the Internet. The cardiac data can be measured and provided directly to the computer thus providing an 'on-line' system. The determination of heart stress can be carried out in the heart data-measuring device directly so that the computer or computers receive a measure of heart stress. Alternatively, the cardiac measurements are sent to the computer or computers for the determination of a cardiac stress measure. The measurements sent to the computer or computers can also be recorded measurements recorded during the execution of the exercise program by the subject so as to provide an 'off-line' system.

The cardiac stress measurements are, in one embodiment, made by taking an ECG signal and by analysing the morphology of the ECG signal. The prior art heart monitoring device described in US patent 5749367 is suitable for providing cardiac measurements that can provide an indication of cardiac stress. Also the heart-monitoring device described in co-pending UK application number 0013504.6 is suitable for providing combined ECG measurements and blood pressure measurements.

The disclosures in US patent number 5749367 and UK application number 0013504.6 are hereby incorporated by reference. In a preferred embodiment the measurement of heart stress is by way of the determination of a heart stress index using morphological features of the ECG signal. Such a heart stress index can be determined in a portable cardiac monitoring device and uploaded to a computer for the determination of the physical exercise program, or it can be determined from cardiac parameters uploaded to a computer from a cardiac measurement device. Thus the device can include a storage means for storing the cardiac data during the exercise program for later uploading to a computer or it can upload the cardiac data in real time during the exercise program to the computer.

The system preferably provides the ability to output an indication of the cardiac stress of the subject to the subject during the physical exercise period to enable the subject to regulate their exercise accordingly. This can for example enable a subject to keep their heart stress with a predetermined range suitable for providing beneficial effects without harmful effects. The output can for example comprise a display or audible information.

The medical history data can be input to the system by any means. For example, if an insurance company has a database of medical history data, this data can be passed to the system for use in the determination of the physical exercise program. Alternatively, during an enrolment procedure, a subject or their physician can enter the data.

The medical data can be used to determine the cardiac risk of the patient. This risk can be used in the determination of the physical exercise program. In one embodiment of the invention, the method includes determining if the medical history data identifies that there is a significant cardiac risk i.e. does the medical history indicate that the subject has or has had a cardiac condition of a high-risk type. If so the subject will be warned by the outputting of a signal that they are not suitable for the exercise programs which can be generated by the system and no exercise program will be generated for them. Alternatively they can be advised to seek medical advice and enrol through a medic who will then have access to their ongoing cardiac data and could take an active part in determining their progress.

In one embodiment, the subject is able to enter feedback data defining their perception of the physical exercise program e.g. how hard it was and whether they enjoyed it. This feedback data can be used to modify the determination of the exercise program. For example, if the subject is not working hard but it feels as though they are or they do not like it, the type of exercise in the program may be changed.

The exercise program can comprise a type of exercise e.g. walking, cycling, running, swimming etc, a frequency of the exercise e.g. twice a week, an intensity of exercise e.g. the resistance or speed, and the duration of the exercise. When a subject enrols, they can indicate the type of facilities that are available to them for exercise. This can be used in the determination of the exercise program to determine the appropriate type of exercise.

In one embodiment of the present invention, once an exercise program has been automatically generated for a subject, before the exercise program is available to the subject a physician must approve the exercise program. The physician can also edit the exercise program if they consider it necessary. In this way responsibility for the prescription of the exercise program falls on the physician.

Another aspect of the present invention provides a programmable exercise machine, which comprises an exercise facility such as a rowing, cycling, stepping, jogging facility to allow the subject to exercise. The exercise facility is controlled by a programmable controller to control the duration, speed and/or resistance experienced by the subject. An input device is provided to allow a machine-readable exercise program and/or a heart stress measurement to be input. The controller controls the exercise facility in accordance with the input machine-readable exercise program. In this way if heart stress is used to control the subject exercise, the exercise facility can be controlled to keep the subject's heart stress within a predetermined range during a prescribed exercise program automatically provided in a controlled manner by the exercise machine. The exercise program can be downloaded to the exercise machine as machine-readable code using any conventional carrier medium e.g. a storage medium such as a floppy disk or CD

ROM or a transient carrier medium i.e. a signal e.g. machine readable code downloaded over the Internet.

A further aspect of the present invention provides a cardiac monitoring method for monitoring a plurality of subjects remotely in which measurements of cardiac function of a subject are take, the measurements are processed to generate cardiac data indicative of the condition of the heart of a subject, the cardiac data is transmitted to a database for storage as a record for the subject, the taking of measurements, the processing of the measurements and the transmitting of the cardiac data are repeated for a plurality of subjects to form a plurality of records, one for each subject, and a medic is provided with an interface to access to the records of a number of subjects for which the medic has medical responsibility.

This aspect provides for the remote cardiac monitoring of a number of patients by a health care worker e.g. a doctor or a nurse. The central database contains a full record of cardiac data to enable the health care worker to monitor the cardiac health of any number of patients.

The present invention can be implemented by computer program code on a general-purpose computer. Thus the present invention is embodied by computer readable code provided to a computer on any suitable carrier medium such as a storage medium e.g. a floppy disk, a CD ROM, a magnetic tape or a programmable memory device, or a transient medium e.g. an electrical or electronics signal, an optical signal or a microwave signal. An example of the supply of computer readable code to a computer using a transient medium is the downloading of code to a computer from a server over the Internet.

An embodiment of the present invention will now be described with reference to the accompanying drawings, in which:
Figure 1 is a schematic diagram of a system for providing exercise programs to a subject in accordance with an embodiment of the present invention;

Figure 2 is a flow chart illustrating the process for determining exercise programs for subjects;

Figure 3 is a flow chart illustrating the risk assessment process of Figure 2;

Figure 4 is a flow diagram illustrating the process of calculating heart stress index;

Figure 5 is a flow diagram illustrating process of determining the next exercise program in Figure 2; and

Figure 6 is a schematic diagram of the organisation of a web site providing the exercise program determination service.

Referring to Figure 1, the embodiment comprises a system implemented over the Internet 1. A heart monitoring device 2 of the type described in US patent number 5749367 or in UK application number 0013504.6 is carried by a subject to provide cardiac measurements. An ECG is taken when the patient carries out the exercise program and it is analysed in the device 2 to determine cardiac conditions and parameters and to record cardiac data in the form of the ECG data and the determined cardiac conditions and parameters. The recorded cardiac data can be uploaded to a computer 3 which can conveniently be the subject's computer, although any Internet connected computer can be used. The cardiac data can be uploaded using the File Transfer Protocol (FTP). The computer 3 will make a connection over the Internet 1 to a server 5 using well known conventional Internet connection procedures. The cardiac data can thus be stored in the database 9 in the server 5 by the database interface application. A web server 7 can be accessed by a web browser on the subject's computer 3 in order to display web pages using the stored web page data 6. Before a subject can upload data, they will be required to register and enrol. These procedures require the subject to enter personal data including medical history data by accessing the web server 7 and the data is entered into the database 9 by the database interface application 8. The database interface application 8, as would be well understood by a skilled person in the art, can comprise any conventional application allowing web-based data entry and retrieval from a database.

The subject's computer 3 is able to access the data in the database 9 via the web server 7 in a conventional manner to enable the subject's data to be reviewed. Also a medic

using another computer 4 with a web browser is able to access the data in the database 9 to review the data and advise where necessary. This enables a medic to provide a remote monitoring facility to enable them to watch the progress of the subjects for which they are responsible. Of course, the database can contain data from many subjects all using the same type of heart monitoring device 2 and computer 3.

The method of operation of the system for the provision of exercise programs will now be described with reference to the flow charts of Figures 2 to 5.

In Figure 2 the method of determining exercise programs is illustrated. In step S1 the subject uses their computer with the browser to access the web site provided on the server 5. At the home page a new subject can login as a new member of the club. The subject will then be required to go through a registration procedure in step S2 where they enter personal data using a form displayed on a web page. The data in this embodiment comprises: name, date of birth, sex, height, weight, medical history (e.g. by ticking boxes for diagnosed conditions such as heart attack, angina, heart failure, hypertension, and high cholesterol), medication (e.g. by ticking boxes for current medication such as beta blocker, anti-arrhythmics, and cardiac glycosides), family history (e.g. tick boxes for a member of their direct family with any of these conditions by the age of 50: heart attack, and angina), health lifestyle e.g. a smoker?, exercise facilities (e.g. tick boxes for exercise facilities available such as somewhere to walk, a bicycle, a video player, a local gym, a local swimming pool, or stairs), the serial number of the heart monitoring device (used to confirm identity since the serial number is transmitted as part of the data by the device), and controlling medic e.g. the medics login code. The entered data is submitted to the database 9 for storage as a subject record by the database interface application. Then in step S3 a Body Mass Index (BMI) is calculated and stored for the subject. The BMI is calculated using the weight and height using the formula:

BMI = weight (kg) / height (m) squared

Thus a new member record is made for the subject and they are assigned a membership number and a password for future access to the site. A member list is maintained in the

database 9 for all members of the club who use the facility. This list is updated when every new member registers.

In step S4 a risk assessment is then performed for the member using the input medical history as will be described in more detail hereinafter with reference to Figure 3. This process determines the level of risk for the subject to be given an exercise program in relation to their medical history. If in step S5 it is determined that the risk is too high, in step S6 a web page is generated telling the subject that no exercise program could be determined for them. If the subject has not been rejected, in step S7 a web page is generated displaying an entry-level exercise program determined based on the subjects risk criterion.

The subject will then use the output exercise program to carry out the assigned program in step S8. In this embodiment the exercise is done off-line and thus the heart-monitoring device 2 worn by the patent records the cardiac data. The recorded cardiac data comprises both a recorded ECG and processed cardiac parameters as described in US patent 5749367 and UK patent application number 0013504.6. The data that is recorded for transfer includes: device serial number, duration of recordal, maximum heart rate, minimum heart rate, arrhythmia, data, ST segment depression, ST segment morphology, ST heart rate, ventricular rate, and ventricular type. In step S9 the subject connects the heart-monitoring device 2 to the computer 3 for the uploading of the cardiac data to the server 5 for storage in the database 9 by the database interface application 8.

When a users accesses the web site, if there has been new cardiac data uploaded, the site will permit the subject to input a reaction to the exercise program. Before the next exercise program can be determined for the subject, they must input a reaction to the exercise program. Thus in step S10 the subject must access the web site and enter a response to the questions:

1. How hard did you find the exercise? – by selecting on a Borg scale from 1 to 10
2. Did you enjoy the exercise? – by selecting from the options:

No, Not much, It was OK, or Yes

This psychological information is stored together with the data from the heart-monitoring device 2 in the database 9. It is also used to calculate the next exercise program for the subject in step S11 as will be described in more detail hereinafter with reference to the flow diagram of Figure 5. The next exercise program for the subject is stored in the database 9. When the subject accesses the web site to retrieve the next exercise program (step S12), in step S13 a risk assessment is again performed for the subject using the cardiac data received from the previous exercise program. If this indicates that there is a risk (step S14) that has been identified as a result of the recordal of the cardiac data, in step S15 a web page is generated telling the subject that no exercise program is available for them. If the subject has not been rejected, in step S16 a web page is generated displaying the next exercise program determined. The process then returns to step S8 wherein the subject performs the exercise routine. Thus in this way exercise programs can be determined based on the result of the previous exercise program.

Before the web page is generated giving the subject the next exercise program, the exercise program can require the approval of the subject's physician or any authorised medical person. The physician or medic can be informed e.g. by email of the generation of a new exercise program for a subject for whom they have medical responsibility. They can then access the web site and approve or edit the exercise program, as they deem necessary. The exercise program then becomes available to the subject as a web page in step S16.

The data for many subjects will be stored in the database 9. In step S17, the data can be collated for the members. This collated data can be used in step S18 to modify or refine the way in which the heart stress index is determined. In this embodiment various cardiac features are used in the calculation of heart stress. By studying the collated data it may be possible to modify the parameters used and their affect on the calculation of the heart stress parameter. Also the collated data can be used to modify or refine the way in which the exercise program is determined. The collated data may help to identify better exercise programs for different categories of subjects.

The process of assessing the risk for a subject (step S4 in Figure 2) will now be described in detail with reference to the flow diagram of Figure 3. In this risk assessment process there are 3 risk categories for which exercise programs will be determined:

1. High Risk (HR) – subjects with previous myocardial infarction (heart attack) or known coronary heart disease.
2. Identified Risk (IR) – subjects with a BMI>30, high blood pressure, or high cholesterol, or diabetics.
3. Worried Well (WW) – subjects who have a family history of cardiac problems, smokers, and all others.

There is also a risk category for excluding subjects from being given exercise programs because it is considered too risky.

The process of determining the risk category will now be described with reference to Figure 3. In step S20 the risk level for a subject is initially set to Worried Well. In step S21 if the subject suffers from hypertension, in step S22 the risk category for the subject is set to Identified Risk. In step S23 if the subject suffers from high cholesterol, in step S22 the risk category for the subject is set to Identified Risk. In step S24 if the subject suffers from diabetes, in step S22 the risk category for the subject is set to Identified Risk. In step S25 if the subject has a Body Mass Index greater than 30, in step S22 the risk category for the subject is set to Identified Risk. In step S26 if the subject has had a heart attack, in step S27 the risk category for the subject is set to High Risk. In step S28 if the subject has angina, in step S27 the risk category for the subject is set to High Risk. In step S29 if the subject has had heart failure, in step S27 the risk category for the subject is set to High Risk. In step S30 if the subject takes beta-blockers, in step S27 the risk category for the subject is set to High Risk. In step S31 if the subject has a left ventricular function that is less than 30%, in step S32 the risk category for the subject is set to reject the subject. In step S33 if the subject has complex ventricular ectopics at a high heart rate, in step S32 the risk category for the subject is set to reject the subject. In step S34 if the subject has a blood pressure that drops on exercise, in step S32 the risk category for the subject is set to reject the subject. In step S35 if the subject has had a complex myocardial infarction, in step S32 the risk category for the subject is set to

reject the subject. In step S36 if the subject has greater than 2mm ST segment depression during a stress test, in step S32 the risk category for the subject is set to reject the subject. In step S37 if the subject has survived a cardiac arrest, in step S32 the risk category for the subject is set to reject the subject. Otherwise in step S38 the risk category is stored in the database 9 for future reference and for use in the determination of a suitable exercise program for the subject.

It will be noted that most of the parameters used in determining whether to reject a subject are available from the input medical history data. However some of it, such as does blood pressure drop on exercise can only be obtained from measurements during exercise. Hence the possibility of rejecting a subject after they have been given an exercise program and the results have been analysed (step S13 S14 and S15).

In accordance with one embodiment of the present invention, the process by which the heart stress index is calculated from cardiac data will now be described in detail with reference to the flow diagram of Figure 4. This process can take place in the heart-monitoring device by suitable programming or in the computer 3. In step S40 a theoretical maximum heart rate MHR is determined as 170 minus the age of the subject. In step S41 it is determined whether the subjects BMI is greater than 30. If so, in step S42 the MHR is set to 160 minus the age of the subject. In step S43 it is then determined whether the subject suffers from hypertension. If so, instep S44 the MHR is set to 150 minus the age of the subject. In step S45 it is then determined whether the subject uses beta-blockers. If so, in step S46 the MHR is set to 70.

In step S47 an initial heart stress index value (HSI) is calculated using the calculated MHR using the equation:

$$HSI = \frac{\text{maxHR} - 50 \times 10}{\text{MHR}}$$

Where maxHR is the measured maximum heart rate from the cardiac data.

Alternatively, the following equation can be used where the minimum measured heart rate minHR is available:

$$HSI = \frac{maxHR - minHR \times 10}{MHR}$$

The calculated initial HSI is then modified dependent upon certain cardiac conditions. In step S48 it is determined whether there is any ST segment depression. If so, in step S49 it is determined whether the subject is taking cardio glycosides. If so, in step S51 the HSI is set to 6 plus the amount of ST segment depression in mm. If not, in step S50 the HSI is set to 7 plus the amount of ST segment depression in mm. In step S52 it is then determined whether there are any ventricular beats in the cardiac data. If so, in step S53 the HSI is modified by the addition of the ventricular rate divided by 10. In step S54 it is then determined whether there was any arrhythmia in the cardiac data. If so, in step S55 the HSI is increased by the number of arrhythmic events. Finally in step S56 the HSI value is rounded down to the nearest whole number and output from the process.

In addition to using the maximum and minimum heart rates, the amount of ST segment depression, and the number of arrhythmias and ventricular beats for the calculation of HSI, ST segment morphology such as whether it is flat, up sloping, or down sloping can be used. Also the heart rate at the maximum ST segment depression, the type of ventricular arrhythmia, blood pressure and breathing rate can be used.

The HSI can be calculated locally in the heart-monitoring device 2, in the subject's computer 3, or in the server 5. If the HSI is not calculated in the device 2, the cardiac data must be transmitted to the computer 3 or the server 5 to enable the calculation. If the HSI is calculated at the device 2, only the HSI need be transmitted. It is however preferable to still send the cardiac data to the server 5 for storage in the database 9 since this allows the data to be reviewed by a medic using their computer 4.

The determination of the exercise program for the subject in accordance with one embodiment of the present invention will now be described in detail with reference to the flow diagram of Figure 5.

The exercise program is based on frequency, duration, intensity and type. The exercise program determination takes three factors into account when making suggestions:

1. Risk analysis of the subjects condition
2. Available facilities and interests
3. Previous performance.

The risk category determination has been described hereinabove with reference to Figure 3.

Facilities that are available to the subject are known from the information entered by the subject during the registration process and can be matched up to intensity requirements using the following matrix, in which the intensity level is given in METs (Metabolic Equivalents):

METs	Walking	Cycling	Swimming	Gym	Video	Stairs
10			X	X		
9			X	X		
8		X	X	X		
7		X		X	X	X
6	X	X		X	X	X
5	X	X		X	X	X
4	X	X		X	X	X
3	X					
2	X					

The entry-level exercise program is determined for each risk category using the following table:

	Frequency	Intensity	Time	Type
High Risk	3 per week	4 mets	15 minutes	Walking
Identified Risk	3 per week	5 mets	20 minutes	From table*
Worried Well	3 per week	6 mets	20 minutes	From table

* walking is suggested as the first start point

After the subject has followed the initial exercise program and provided their feedback, the next exercise program can be determined for the subject. As a basic rule, the exercise program should only be changed in two ways:

to vary the type to avoid boredom

to change the exercise intensity and time as the subject progresses.

If the feedback shows a value of **no** or **not much** for the enjoyment of the session then the Type should be changed according to the facilities available.

Intensity and time changes are more delicate to change, the time should be increased before the intensity and only when the HSI and the Borg scale feedback both show that the previous session was achieved with ease. Changes can be made using the logic illustrated in the flow diagram of Figure 5.

At this point, if the subject's response was negative (i.e. a high number on the Borg scale), or if the HSI was high, a message e.g. an email could be automatically sent to the subject's physician or medically responsible person.

In step S60 the process of determining the next exercise program starts. In step S61 it is determined whether the HSI is less than 7 and the Borg value is less than 5. If so, in step S62 it is determined whether the duration of the exercise is less than 40. If so, in step S65 the duration of the exercise is increased by 5 minutes and in step S64 the next exercise program is formed. If in step S62 the duration of the exercise program is 40 minutes (the maximum at any intensity), in step S63 the intensity is increased by one and the duration is reset to 20 minutes. The next exercise program is then formed in step S64. If in step S61 the HSI is not less than 7 and the Borg value is not less than 5, in step S66 it is determined whether the HSI is greater than 8 or the Borg value is greater than 6. If so, in step S67 it is determined whether the duration of the exercise is greater than 20 minutes. If so, the duration of the exercise program is reduced by 5 minutes in step S69 and the next exercise program is formed in step S64. If in step S67 it is determined that the duration is not greater than 20 minutes, in step S68 the intensity is

decreased by one and the duration is reset to 30 minutes and the next exercise program is formed in step S64.

If in step S66 it is determined that the HSI is not greater that 8 or the Borg value is not greater than 6, in step S70 no changes are made to the exercise program and the unchanged exercise program is formed as the next exercise program in step S64.

Thus this process will change the exercise program to increase the duration up to a maximum or increase the intensity if the duration is at a maximum when it is determined that the subject is not working hard during the exercise program i.e. the HSI is not high enough and if the subject felt that they were not working very hard i.e. their input Borg value was low. Also if the subject is working too hard i.e. their HSI is too high or if they feel they are working too hard i.e. their input Borg value is high, the duration of the exercise routine is reduced or if the duration is at a minimum, the intensity is reduced.

The exercise program can be for a period of time such as a week and the frequency will tell the subject how often to do the exercise during the period. At the end of the period the subject will be required to connect to the server, download the cardiac data, and enter their feedback in order to get the next exercise program for the next period e.g. for the next week. It is however not essential that the subject wait until the end of the period before connecting to the server. If the system detects a cardiac problem with the subject, a message can be sent to the subject e.g. an email to warn the subject to seek medical advice.

In addition to asking for the feedback from the subject on how hard the exercise was and did they enjoy it, they could also be asked whether they followed the exercise routine. There is no point in changing the routine if, for whatever reason the subject was unable to execute the program. Thus this additional piece of feedback information can be used to avoid changing the program if it was not executed.

The selection of the type of exercise program can also take into account the physical capabilities and disposition of the subjects. For example, people of higher body mass frequently find swimming easier than cycling or walking because of their natural buoyancy. They would thus find this exercise easier. Also subjects may have personal preferences that will be reflected in their feedback i.e. they may say that the exercise was hard when really it was not, it was just that they disliked it and it thus subconsciously felt more difficult. Such discrepancies between the HSI and the Borg values can be identified and compensated for when determining an appropriate exercise program for a subject.

Figure 6 schematically illustrates the organisation of the web site in one embodiment of the present invention. The Home Page comprises a Login page enabling a member to login or a new member to login as a visitor. Also a medic can login to review data. To login a username and password is required. A member can access a reception page having links to information about the club, to a page allowing new members to join, and to a page giving contacts to which emails can be sent. A notice board page can also be accessed with links to news, events and email. A club lounge page can also be accessed which provides a bulletin board and links to other sites of interest. A consulting room page can also be accessed allowing a subject to enter their feedback to their exercise program at this page and receive cardiac educational information. They can also access their data comprising history data for their previous exercise programs. This can comprise The date, the exercise type, the intensity, the duration, the maximum heart rate achieved, the HSI, and the subjects feedback information i.e. how hard it was for them and how it felt. A gym page can also be accessed. If a subject accesses this page and they have not input their feedback, the questions will be put to them requiring an answer before a new exercise program will be given. In the gym area an exercise program can be obtained as well as training advice. A shop page can also be accessed allowing the purchase of equipment and other products.

When a medic accesses the site, they can access a records page to review the progress of selected subjects or to obtain detailed reports on subjects. The information available to the medic is far more detailed that that available to the subject. All of the cardiac data available from the device 2 is available for each exercise program in the history. This

enables the medic to look carefully at the cardiac function of the subject over any number of exercise programs. The data is preferable not just restricted to the HSI value but also includes the cardiac data used to determine the HSI. The medic also has access to a library page to view material available and to see links to other relevant sites. A notice board page is also available where general news is present and other views and events are posted. Also an email tool is available to email other members. A staff lounge page is also available to medics and this contains a bulletin board and a description of the next on-line conference.

Although the present invention has been described hereinabove with reference to a specific embodiment, it will be apparent to a skilled person that other embodiments lie within the spirit and scope of the present invention.

The present invention can be implemented in single processing apparatus that receives cardiac data. The present invention can also be implemented in a distributed manner over a network of computers in which data is received in one computer and possible partly processed and transmitted to another computer for further processing. The present invention also encompasses a complete heart monitoring and exercise program determining apparatus. Further, the present invention encompasses the use of wireless communications from a heart monitoring apparatus to a computer e.g. using the Wireless Application Protocol (WAP). Communications between the device and the computer could be automatic. The device could even be an implanted cardiac monitor.

The present invention is applicable to any measure of heart stress and particularly to a measure that uses information on the morphology of the functioning of the heart.

The invention also encompasses the ability of the system to contact the subject automatically if they have not connected to the system for a while e.g. an email could be sent to the subject if they have not connected within a predetermined period after expiry of their current exercise period in order to get their next exercise program.

The heart monitoring device can include the ability to calculate the heart stress index and this can be output e.g. visually or audibly to a subject to enable them to regulate their exercise to keep the HSI within a predetermined range that will exercise the heart without placing undue stress on it. The exercise program given to the subject can thus include directions as to the predetermined range within which the subject should keep their HSI.

The subject can be any animal. However the system is particularly suited for use on humans. The system can be used by anyone who has a concern about their heart or physical fitness. The system is however particularly useful for patients in cardiac rehabilitation. It enables them to carry out an exercise program without attending a specialist clinic whilst still being monitored to manage their progress.

The system can also cause a message to automatically be sent to a medic responsible for a subject when the heart monitoring device detects that the HSI reaches a high value. The medics is able to review the full cardiac history of the patient including recorded ECGs of at least appropriate segments where a cardiac event was detected and take the necessary action.
The system could also make use of additional physiological measurements as part of the HSI calculation including blood pressure, pulse oximetry, breathing rate and VO_2 information. Blood pressure response to exercise in particular would provide valuable information.

The real time calculation of HSI during exercise could also be used as an input to a programmable exercise machine such as a treadmill, cycle erometer or rowing machine. Such a system would allow the programmable exercise machine to vary its resistance setting to maintain the users HSI in a desirable band. As HSI went above the desired band the machine would reduce the workload until the HSI had decreased, conversely if HSI fell below the desired band the machine would increase the workload.

A programmable exercise machine such as the one described above could also accept a complete exercise programme including warm up, main exercise and cool down parameters derived by an exercise prescription system.

CLAIMS:

1. A method of generating a physical exercise program for a subject, the method comprising:

receiving data on the medical history of the subject;

outputting data describing an initial physical exercise program;

receiving cardiac data indicative of the level of heart stress of the subject during the exercise program;

determining a physical exercise program for the subject on the basis of the received medical history data and the received cardiac data; and

outputting data describing the determined physical exercise program.

2. A method according to claim 1, wherein the received cardiac data is derived from electrocardiograph data.

3. A method according to claim 2, wherein the received cardiac data includes data on the morphology of the electrocardiograph data.

4. A method according to any preceding claim, including determining if the medical history data identifies any predefined excluded conditions, and outputting data indicating that a physical exercise program is not available if it is determined that the medical history data identifies any of the predefined excluded conditions.

5. A method according to any preceding claim, including receiving feedback data from a subject defining how the physical exercise program was perceived by the user, wherein the feedback data is used with the medical history data and the cardiac data in the determination of the physical exercise program.

6. A method according to any preceding claim, wherein the physical exercise program comprises a type of exercise, a frequency of the exercise, an intensity of the exercise and duration of the exercise.

7. A method according to claim 7, wherein during an initial phase, facility data identifying the type of facilities available to the subject is received and the facility data is used to determine an appropriate exercise type in the physical exercise program.

8. A method according to any preceding claim, wherein the received data is stored and is accessible to the subject and to a medic.

9. A method according to any preceding claim, wherein the cardiac data is received over a communications network.

10. A method according to claim 9, including recording the cardiac data in a portable device during the exercise program and subsequently transmitted to a remote processing unit for the generation of the physical exercise program.

11. A method according to claim 9 or claim 10, wherein the data describing the physical exercise program is transmitted over the communications network to an apparatus for output to the subject.

12. A method according to any preceding claim, wherein the receiving of cardiac data, the determining of a physical exercise program and the outputting of data describing the determined physical exercise program are repeated to determine new exercise programs for the subject.

13. A cardiac rehabilitation method comprising:

providing data on the medical history of a subject undergoing cardiac rehabilitation;

outputting an initial physical exercise program to the subject;

taking measurements of the cardiac stress experienced by the subject during the exercise program;

determining a next physical exercise program for the subject on the basis of the measurements and the medical history data;

outputting the next physical exercise program to the subject; and

repeating the taking of the measurements, the determining of the next physical exercise program, and the outputting of the next physical exercise program.

14. A cardiac rehabilitation method according to claim 13, wherein the taking of measurements includes the taking of an electrocardiogram and the processing of the electrocardiogram to determine cardiac stress from morphological features of the electrocardiogram.

15. A cardiac rehabilitation method according to claim 13 or claim 14, including comparing the medical history data with excluded medical conditions and outputting a warning that no exercise program is available if a medical condition in the medical history is found to match an excluded medical condition.

16. A cardiac rehabilitation method according to any one of claims 13 to 15, including receiving input from the subject giving their subjective opinion on their experience carrying out the exercise program, wherein the determination of the next physical exercise program takes into account the received input.

17. A cardiac rehabilitation method according to any one of claims 13 to 16, wherein the exercise program is input to an exercise machine and used to control the exercise machine during exercise by the subject.

18. A cardiac rehabilitation method according to claim 17, wherein the cardiac stress measurements are further used to control the exercise machine.

19. A cardiac rehabilitation method according to claim 18, wherein the resistance offered by the exercise means to the subject is decreased if the cardiac stress measurements increase above a threshold, and increased if the cardiac stress measurements decrease below a threshold.

20. Apparatus for generating a physical exercise program for a subject, the apparatus comprising:

medical data receiving means for receiving data on the medical history of the subject;

outputting means for outputting data describing an initial physical exercise program;

heart stress receiving means for receiving cardiac data indicative of the level of heart stress of the subject during the exercise program; and

determining means for determining a physical exercise program for the subject on the basis of the received medical history data and the received cardiac data;

wherein said outputting means is arranged to output data describing the determined physical exercise program.

21. Apparatus according to claim 20, wherein the received cardiac data is derived from electrocardiograph data.

22. Apparatus according to claim 21, wherein the received cardiac data includes data on the morphology of the electrocardiograph data.

23. Apparatus according to any one of claims 20 to 22, including determining means for determining if the medical history data identifies any predefined excluded conditions, wherein said outputting means is adapted to output data indicating that a physical exercise program is not available if it is determined that the medical history data identifies any of the predefined excluded conditions.

24. Apparatus according to any one of claims 20 to 23, including means for receiving feedback data from a subject defining how the physical exercise program was perceived by the user, wherein said determining means is adapted to use the feedback data with the medical history data and the cardiac data in the determination of the physical exercise program.

25. Apparatus according to any one of claims 20 to 24, wherein determining means is adapted to determine the physical exercise program in the form of a type of exercise, a frequency of the exercise, an intensity of the exercise and a duration of the exercise.

26. Apparatus according to claim 25, including facility data input means for, during an initial phase, inputting facility data identifying the type of facilities available to the subject, wherein said determining means is adapted to use the facility data to determine an appropriate exercise type in the physical exercise program.

27. Apparatus according to any one of claims 20 to 26, including storage means for storing the received data in a form which is accessible to the subject and to a medic.

28. Apparatus according to any one of claims 20 to 27, wherein the cardiac data receiving means is adapted to receive the cardiac data over a communications network.

29. Apparatus according to claim 28, comprising a processing unit comprising said medical data receiving means, said outputting means, said heart stress receiving means, and said determining means; and including a portable device having recording means for recording the cardiac data during the exercise program and transmitting means for subsequently transmitting the cardiac data to said processing unit for the generation of the physical exercise program.

30. Apparatus according to claim 28 or claim 29, including means for transmitting the data describing the physical exercise program over the communications network to an apparatus for output to the 20.

31. Apparatus according to any one of claims 17 to 30, wherein the cardiac data receiving means, the determining means and the outputting means are adapted to repeat the determination of new exercise programs for the subject.

32. A cardiac rehabilitation apparatus comprising:
providing means for providing data on the medical history of a subject undergoing cardiac rehabilitation;

outputting means for outputting an initial physical exercise program to the subject;

measuring means for taking measurements of the cardiac stress experienced by the subject during the exercise program; and

determining means for determining a next physical exercise program for the subject on the basis of the measurements and the medical history data;

wherein said outputting means is adapted to output the next physical exercise program to the subject; and said measuring means, said determining means and said outputting means are adapted to repeat the taking of the measurements, the determination of the next physical exercise program, and the outputting of the next physical exercise program respectively.

33. A cardiac rehabilitation apparatus according to claim 32, wherein said measuring means is adapted to take an electrocardiogram and process the electrocardiogram to determine cardiac stress from morphological features of the electrocardiogram.

34. A cardiac rehabilitation apparatus according to claim 32 or claim 33, including means for comparing the medical history data with excluded medical conditions and means for outputting a warning that no exercise program is available if a medical condition in the medical history is found to match an excluded medical condition.

35. A cardiac rehabilitation apparatus according to any one of claims 32 to 34, including means for receiving input from the subject giving their subjective opinion on their experience carrying out the exercise program, wherein said determining means is adapted to determine the next physical exercise program taking into account the received input.

36. Apparatus for generating a physical exercise program for a subject, the apparatus comprising:

a memory device containing program code for controlling a processor; and a processor for implementing the stored program code;

wherein the stored program code includes code for controlling the processor to: receive data on the medical history of the subject;

output data describing an initial physical exercise program;

receive cardiac data indicative of the level of heart stress of the subject during the exercise program;

determine a physical exercise program for the subject on the basis of the received medical history data and the received cardiac data; and

output data describing the determined physical exercise program.

37. Apparatus according to claim 36, wherein the received cardiac data is derived from electrocardiograph data.

38. Apparatus according to claim 37, wherein the received cardiac data includes data on the morphology of the electrocardiograph data.

39. Apparatus according to any one of claims 36 to 38, wherein the stored program code includes code for controlling the processor to determine if the medical history data identifies any predefined excluded conditions, and to output data indicating that a physical exercise program is not available if it is determined that the medical history data identifies any of the predefined excluded conditions.

40. Apparatus according to any one of claims 36 to 39, wherein the stored program code includes code for controlling the processor to receive feedback data from a subject defining how the physical exercise program was perceived by the user, and to use the feedback data with the medical history data and the cardiac data in the determination of the physical exercise program.

41. Apparatus according to any one of claims 36 to 40, wherein the physical exercise program comprises a type of exercise, a frequency of the exercise, an intensity of the exercise and duration of the exercise.

42. Apparatus according to claim 41, wherein the stored program code includes code for controlling the processor to, during an initial phase, receive facility data identifying the type of facilities available to the subject and to use the facility data to determine an appropriate exercise type in the physical exercise program.

43. Apparatus according to any one of claims 36 to 42, wherein the stored program code includes code for controlling the processor to store the received data to be accessible to the subject and to a medic.

44. Apparatus according to any one of claims 36 to 43, wherein the cardiac data is received over a communications network.

45. Apparatus according to claim 44, wherein the stored program code includes code for controlling the processor to transmit the data describing the physical exercise program over the communications network to an apparatus for output to the subject.

46. Apparatus according to any one of claims 36 to 45, wherein the stored program code includes code for controlling the processor to repeat the receiving of cardiac data, the determining of a physical exercise program and the outputting of data describing the determined physical exercise program to determine new exercise programs for the subject.

47. A cardiac rehabilitation apparatus comprising:

a memory device containing program code for controlling a processor; and a processor for implementing the stored program code;

wherein the stored program code includes code for controlling the processor to: receive data on the medical history of a subject undergoing cardiac rehabilitation; output an initial physical exercise program to the subject;

take measurements of the cardiac stress experienced by the subject during the exercise program;

determine a next physical exercise program for the subject on the basis of the measurements and the medical history data;

output the next physical exercise program to the subject; and repeat the taking of the measurements, the determining of the next physical exercise program, and the outputting of the next physical exercise program.

48. A cardiac rehabilitation apparatus according to claim 47, wherein the stored program code includes code for controlling the processor to take the measurements by taking an electrocardiogram and processing the electrocardiogram to determine cardiac stress from morphological features of the electrocardiogram.

49. A cardiac rehabilitation apparatus according to claim 47 or claim 48, wherein the stored program code includes code for controlling the processor to compare the medical history data with excluded medical conditions and to output a warning that no exercise program is available if a medical condition in the medical history is found to match an excluded medical condition.

50. A cardiac rehabilitation apparatus according to any one of claims 47 to 49, wherein the stored program code includes code for controlling the processor to receive input from the subject giving their subjective opinion on their experience carrying out the exercise program, and to determine the next physical exercise program taking into account the received input.

51. A carrier medium carrying computer readable code for controlling a computer to carry out the method of any one of claims 1 to 19.

52. A programmable exercise machine comprising exercise means for allowing a subject to exercise, programmable control means for controlling the exercise means in dependence upon an input heart stress measurement, and input means for inputting a heart stress measurement.

53. A programmable exercise machine according to claim 52, wherein said control means is adapted to decrease the resistance offered by the exercise means to the subject if the input heart stress measurement increases above a threshold, and increase the resistance offered by the exercise means to the subject if the input heart stress measurement decreases below a threshold.

54. A programmable exercise machine according to claim 52 or claim 53, wherein said input means is adapted to receive an exercise program in machine readable form and said control means is adapted to control said exercise means in dependence on the input exercise program.

55. A method of controlling an exercise machine comprising inputting a heart stress measurement for a subject exercising and controlling the exercise machine in dependence upon the input heart stress measurement.

56. A method according to claim 55, wherein the resistance offered by the exercise means to the subject is decreased if the input heart stress measurement increases above a threshold, and increased if the input heart stress measurement decreases below a threshold.

57. A method according to claim 55 or claim 56, wherein an exercise program is input in machine readable form and the exercise program is further controlled in dependence upon the input exercise program.

58. A method according to claim 57, wherein the exercise program is generated using the method of any one of claims 1 to 12.

59. A cardiac monitoring method for monitoring a plurality of patients remotely, the method comprising:

taking measurements of cardiac function of a subject;

processing the measurements to generate cardiac data indicative of the condition of the heart of a subject;

transmitting the cardiac data to a database for storage as a record for the subject;

repeating the taking of measurements, the processing of the measurements and the transmitting of the cardiac data for a plurality of subjects to form a plurality of records, one for each subject; and

allowing a medic access to the records of a number of subjects for which the medic has medical responsibility.

60. A cardiac monitoring apparatus for use in the method of claim 59, comprising: receiving means for receiving cardiac data indicative of the condition of the heart of a plurality of subjects;

database means for storing the received cardiac data as a record for each subject; and

interface means allowing a medic access to the records of a number of subjects for which the medic has medical responsibility.

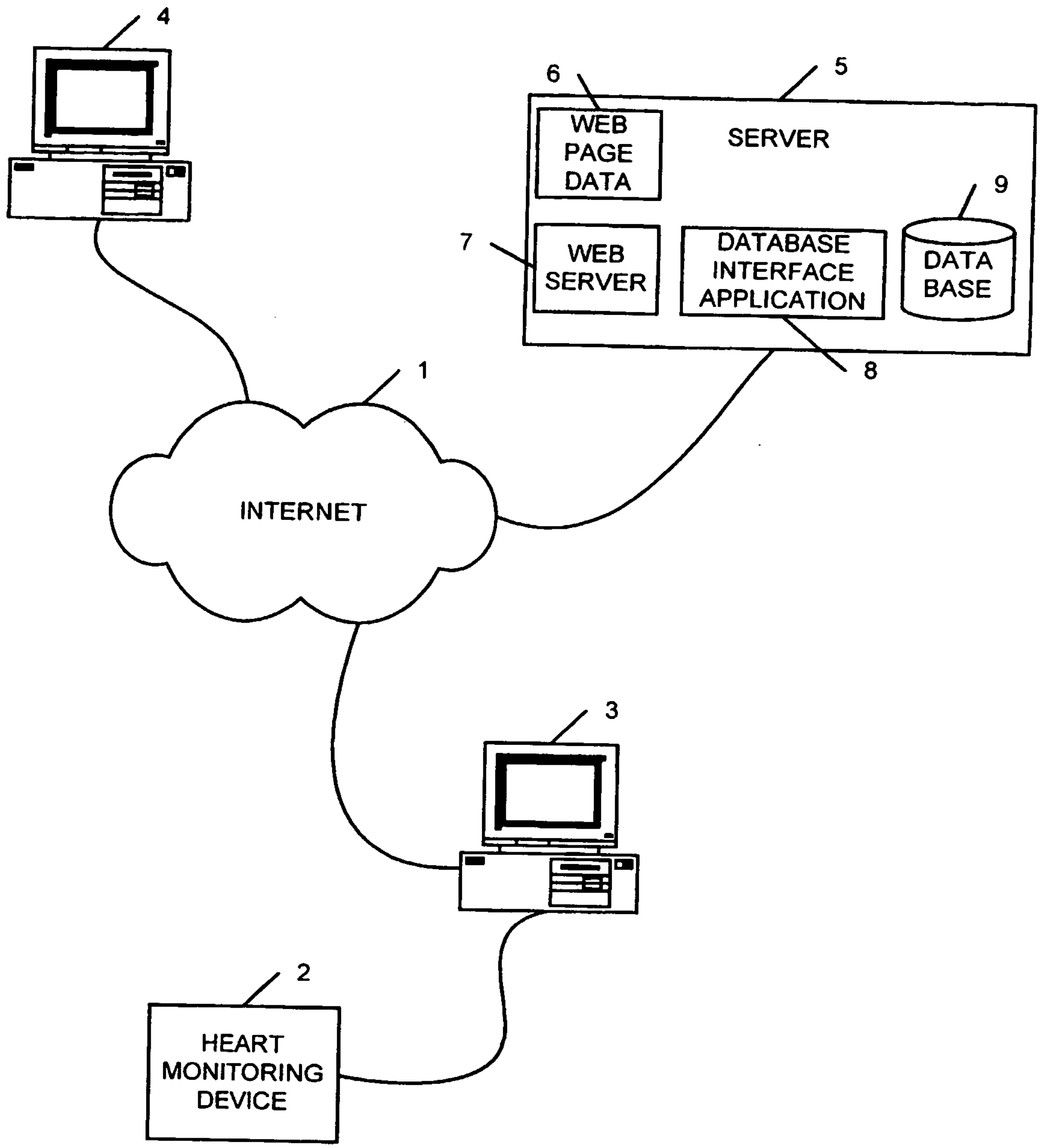

4
6
5
WEB PAGE DATA
SERVER
9
7
WEB SERVER
DATABASE INTERFACE APPLICATION
DATA BASE
8
1
INTERNET
3
2
HEART MONITORING DEVICE

Fig 1

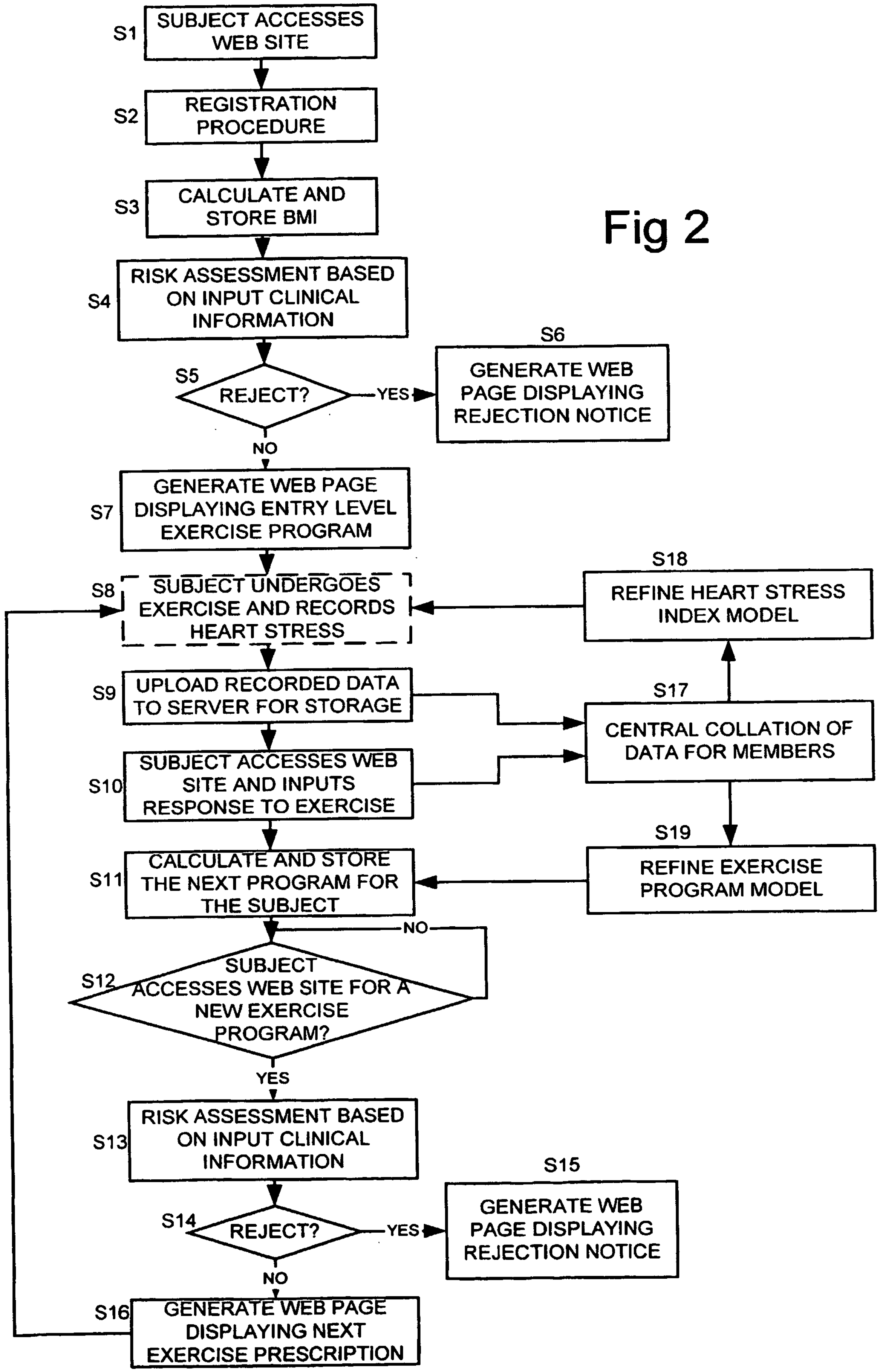

S1 SUBJECT ACCESSES WEB SITE
S2 REGISTRATION PROCEDURE
S3 CALCULATE AND STORE BMI
S4 RISK ASSESSMENT BASED ON INPUT CLINICAL INFORMATION
S5 REJECT?
YES
S6 GENERATE WEB PAGE DISPLAYING REJECTION NOTICE
NO
S7 GENERATE WEB PAGE DISPLAYING ENTRY LEVEL EXERCISE PROGRAM
S8 SUBJECT UNDERGOES EXERCISE AND RECORDS HEART STRESS
S18 REFINE HEART STRESS INDEX MODEL
S9 UPLOAD RECORDED DATA TO SERVER FOR STORAGE
S17 CENTRAL COLLATION OF DATA FOR MEMBERS
S10 SUBJECT ACCESSES WEB SITE AND INPUTS RESPONSE TO EXERCISE
S19 REFINE EXERCISE PROGRAM MODEL
S11 CALCULATE AND STORE THE NEXT PROGRAM FOR THE SUBJECT
NO
S12 SUBJECT ACCESSES WEB SITE FOR A NEW EXERCISE PROGRAM?
YES
S13 RISK ASSESSMENT BASED ON INPUT CLINICAL INFORMATION
S14 REJECT?
YES
S15 GENERATE WEB PAGE DISPLAYING REJECTION NOTICE
NO
S16 GENERATE WEB PAGE DISPLAYING NEXT EXERCISE PRESCRIPTION

Fig 2

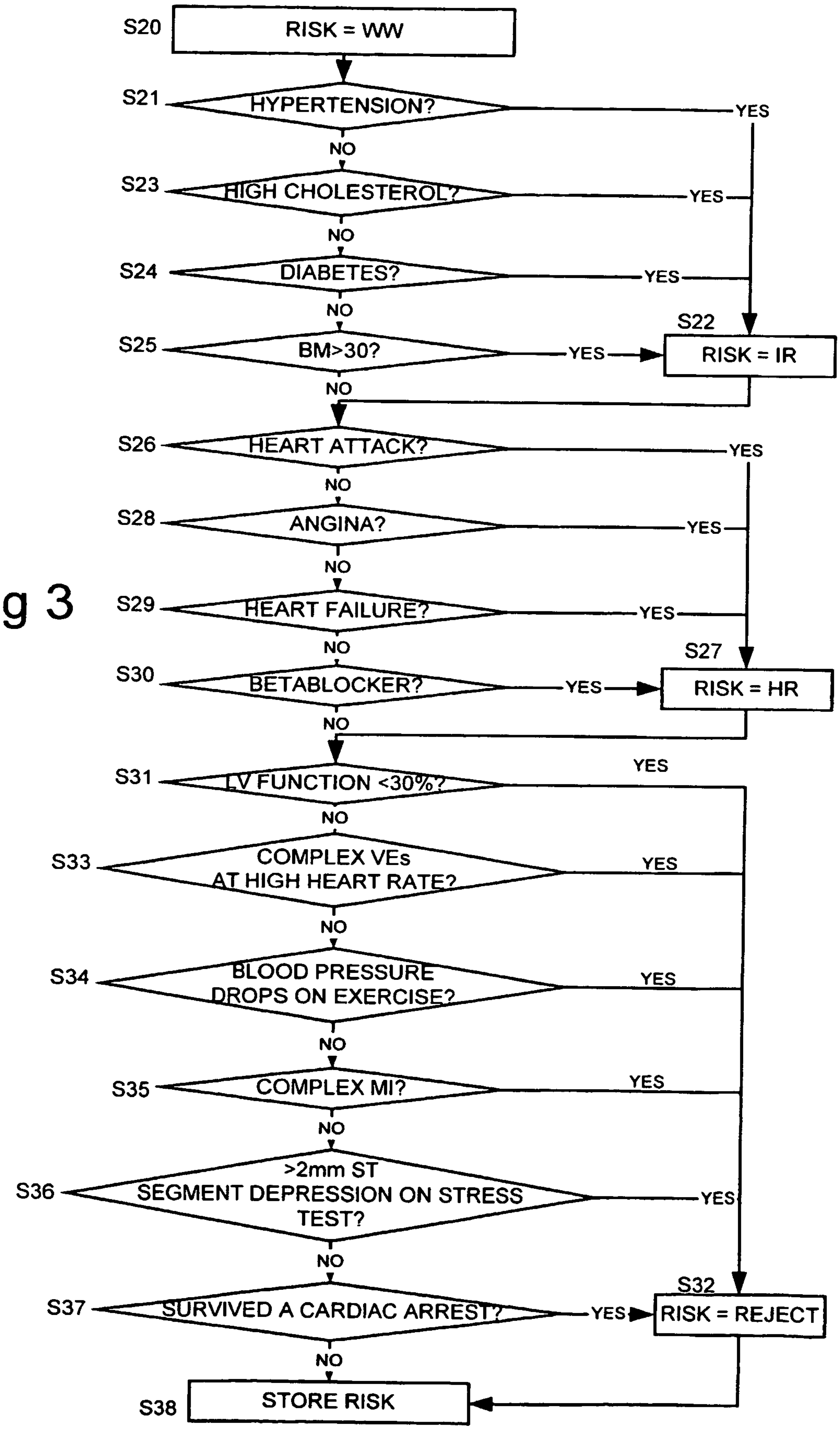

S20
RISK = WW
S21
HYPERTENSION?
YES
NO
S23
HIGH CHOLESTEROL?
YES
NO
S24
DIABETES?
YES
NO
S22
S25
BM>30?
YES
RISK = IR
NO
S26
HEART ATTACK?
YES
NO
S28
ANGINA?
YES
NO
S29
HEART FAILURE?
YES
NO
S27
S30
BETABLOCKER?
YES
RISK = HR
NO
YES
S31
LV FUNCTION <30%?
NO
S33
COMPLEX VEs
AT HIGH HEART RATE?
YES
NO
S34
BLOOD PRESSURE
DROPS ON EXERCISE?
YES
NO
S35
COMPLEX MI?
YES
NO
S36
>2mm ST
SEGMENT DEPRESSION ON STRESS
TEST?
YES
NO
S32
S37
SURVIVED A CARDIAC ARREST?
YES
RISK = REJECT
NO
S38
STORE RISK

Fig 3

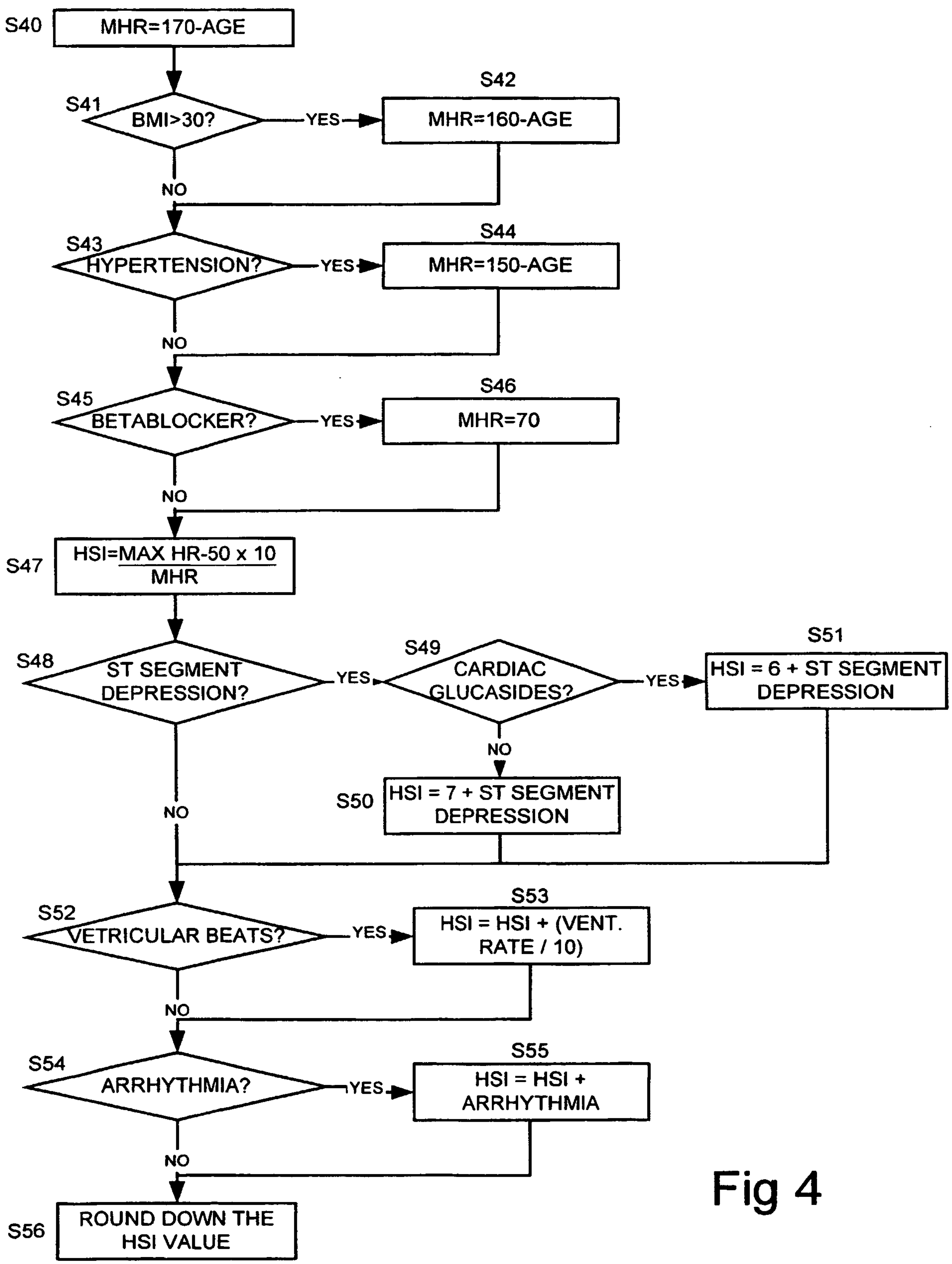

S40
MHR=170-AGE
S41
BMI>30?
YES
S42
MHR=160-AGE
NO
S43
HYPERTENSION?
YES
S44
MHR=150-AGE
NO
S45
BETABLOCKER?
YES
S46
MHR=70
NO
S47
HSI=MAX HR-50 x 10 / MHR
S48
ST SEGMENT DEPRESSION?
YES
S49
CARDIAC GLUCASIDES?
YES
S51
HSI = 6 + ST SEGMENT DEPRESSION
NO
S50
HSI = 7 + ST SEGMENT DEPRESSION
NO
S52
VETRICULAR BEATS?
YES
S53
HSI = HSI + (VENT. RATE / 10)
NO
S54
ARRHYTHMIA?
YES
S55
HSI = HSI + ARRHYTHMIA
NO
S56
ROUND DOWN THE HSI VALUE

Fig 4

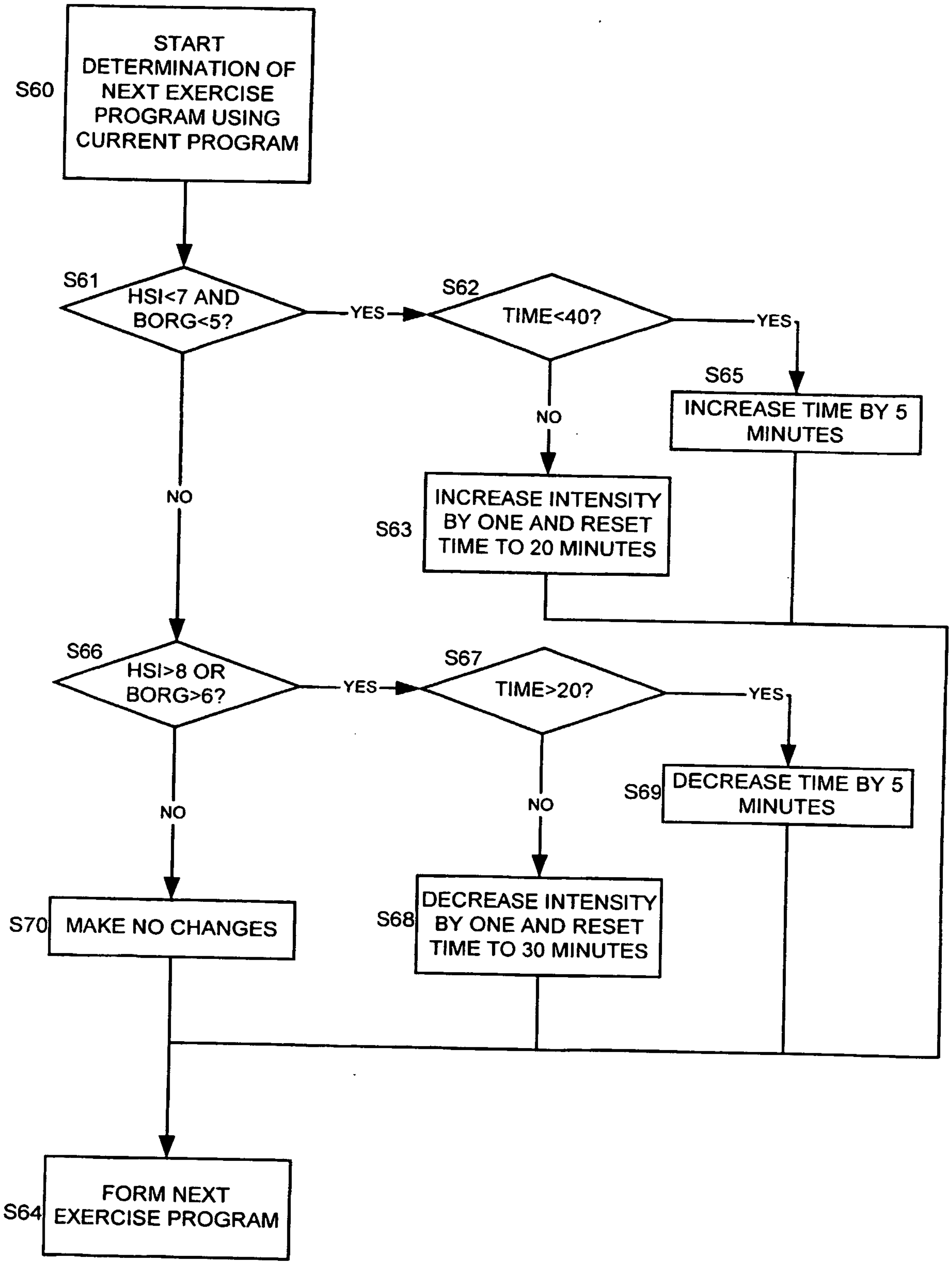
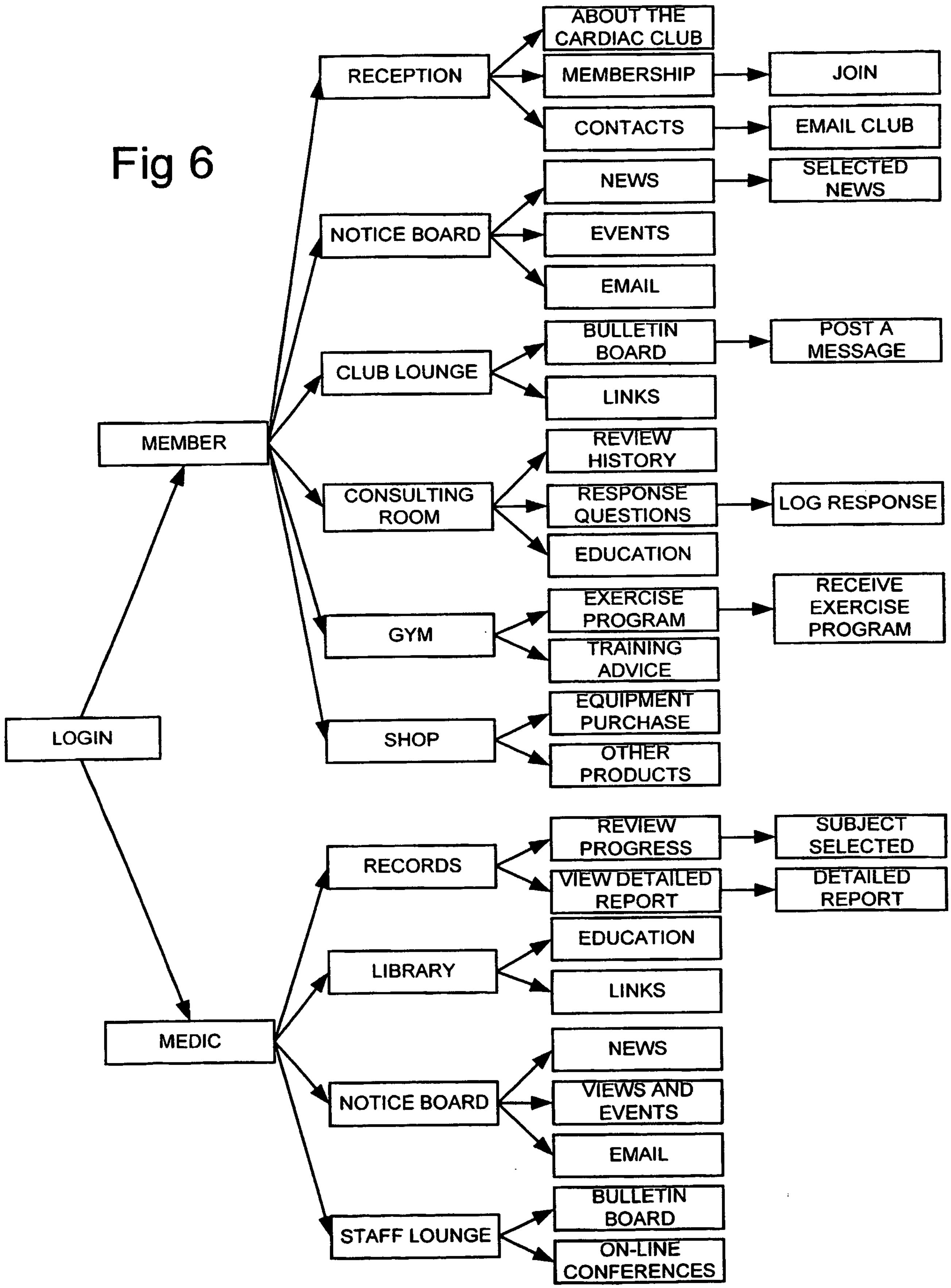

S60
START DETERMINATION OF NEXT EXERCISE PROGRAM USING CURRENT PROGRAM
S61
HSI<7 AND BORG<5?
YES
S62
TIME<40?
YES
S65
INCREASE TIME BY 5 MINUTES
NO
S63
INCREASE INTENSITY BY ONE AND RESET TIME TO 20 MINUTES
NO
S66
HSI>8 OR BORG>6?
YES
S67
TIME>20?
YES
S69
DECREASE TIME BY 5 MINUTES
NO
S68
DECREASE INTENSITY BY ONE AND RESET TIME TO 30 MINUTES
NO
S70
MAKE NO CHANGES
S64
FORM NEXT EXERCISE PROGRAM

Fig 5

Fig 6


LOGIN
MEMBER
MEDIC
RECEPTION
ABOUT THE CARDIAC CLUB
MEMBERSHIP
JOIN
CONTACTS
EMAIL CLUB
NOTICE BOARD
NEWS
SELECTED NEWS
EVENTS
EMAIL
CLUB LOUNGE
BULLETIN BOARD
POST A MESSAGE
LINKS
CONSULTING ROOM
REVIEW HISTORY
RESPONSE QUESTIONS
LOG RESPONSE
EDUCATION
GYM
EXERCISE PROGRAM
RECEIVE EXERCISE PROGRAM
TRAINING ADVICE
SHOP
EQUIPMENT PURCHASE
OTHER PRODUCTS
RECORDS
REVIEW PROGRESS
SUBJECT SELECTED
VIEW DETAILED REPORT
DETAILED REPORT
LIBRARY
EDUCATION
LINKS
NOTICE BOARD
NEWS
VIEWS AND EVENTS
EMAIL
STAFF LOUNGE
BULLETIN BOARD
ON-LINE CONFERENCES